logical enhancement and sensory gratification. Future research needs to address and compare the possible mechanisms. Regardless of which mechanisms are operating, the relationship between stress and smoking undoubtedly reinforces habitual tobacco use and may contribute to initiation and relapse.

Tobacco Use, Nicotine, and Body Weight

Cigarette smokers weigh less than comparably aged nonsmokers, and many smokers who quit smoking gain weight (Grunberg 1986a; Rodin and Wack 1984; Wack and Rodin 1982). It has been suggested that some people smoke to prevent weight gain as the result of smoking cessation (Birch 1975; Charlton 1984b; Grunberg 1986a). Therefore, methods to control weight gain following cessation have been recommended (Birch 1975; Ducimetiere et al. 1978; Grinstead 1981; Grunberg and Bowen 1985a). How much weight gain actually occurs following smoking cessation (Albanes et al. 1987; Bosse, Garvey, Costa 1980; Rabkin 1984; Wack and Rodin 1982), the specific mechanisms (i.e., changes in dietary intake, physical activity, and/or changes in resting metabolic rate) responsible for this weight gain (Grunberg 1986b; Hofstetter et al. 1986), and whether weight gain (or fear of weight gain) affects either cessation or relapse efforts (Hall, Ginsberg, Jones 1986; Klesges and Klesges, in press; Kramer 1982) remain controversial. This Section reviews data relevant to the smoking/body weight relationship.

The Relationship Between Smoking and Body Weight

The relationship between smoking and body weight has been extensively examined and reported for more than 100 years (Kitchen 1889; Otis 1884). Human studies can be summarized into two broad areas: (1) cross-sectional evaluations that have compared the weights of smokers, nonsmokers, and in some cases, ex-smokers; and (2) longitudinal, within-subject evaluations that have measured weight changes in smokers, ex-smokers, and nonsmokers over time. The cross-sectional evaluations reported since 1970 are tabulated in Table 2, and the longitudinal studies reported since 1970 are summarized in Table 3. Both tables present the reference and year, a brief description of the sample design, major findings, observed moderator variables (e.g., gender, number of cigarettes per day) for weight, and major limitations of the study. Only studies published

Of the 28 cross-sectional evaluations presented in Table 2, 25 (89 percent) reported that smokers weigh less than nonsmokers. An additional study (Sutherland et al. 1980) found this relationship for women but not for men and another study (Hjermann et al. 1976) found this relationship for older (45 to 49 years) but not younger (40 to 44 years) men. Only one study did not report an inverse relationship between smoking and body weight, and that study examined visitors to a "health exhibit," a population that may be health conscious and predisposed to making positive health changes (Waller and Brooks 1972). This one discrepant study included a high percentage of cigar and pipe smokers (many of whom do not inhale). While it is difficult to summarize the cross-sectional studies because of differences in reporting techniques, it was found that smokers overall weighed an average of 7.13 lb (range: 2.36 to 14.99) less than nonsmokers.

Because smoking and alcohol consumption are correlated, one study (Williamson et al. 1987) examined, through multivariate methods, the effects of smoking and alcohol consumption on body weight. This study reported that alcohol consumption accounted for approximately 44 percent of the reduction in body weight in women who smoked compared with women who did not smoke. For men, statistical adjustment for alcohol consumption did not alter the weight-lowering effect of smoking.

Cigarette consumption, age, and gender have been adequately evaluated to reach some conclusions regarding their impact on the relationship between smoking and body weight. The effect of cigarette consumption has been parametrically evaluated in eight studies. Six (Albanes et al. 1987; Hjermann 1976; Holcomb and Meigs 1972; Jacobs and Gottenborg 1981; Khosla and Lowe 1971; Lincoln 1970; Stephens and Pederson 1983) of the eight investigations (75 percent) reported a curvilinear relationship. In all of these reports, nonsmokers had the greatest body weights; moderate smokers (typically 10 to 20 cigarettes/day) had the lowest body weights; and heavy smokers (typically >20 cigarettes/day) had body weights approaching that of nonsmokers. Two studies (Bjelke 1971; Kopczynski 1972) reported no relationship between level of smoking and weight.

The effect of age on the smoking/body weight relationship was examined in six investigations. Five of six studies (86 percent) (Albanes et al. 1987; Bjelke 1971; Hjermann et al. 1976; Jacobs and

TAB | Study | Albanes (1987) | Andrews McGarry (1972) | Biener (1983) | Blair et al (1980)

TABL | Study | Bjelke (1971) | Feldy e (1984) | Fisher et al (1985) | Friedman (1981)

TABLE 2.—Continued

Study	Design and sample	Major results	Moderator variables	Limitations
Garn et al. (1978b)	17,649 pregnant women, national health survey	Smoking mothers prepregnancy weight less than nonsmoking mothers; difference: whites 2.43 lb, blacks 3.53 lb	SES and race: no smoking/weight relationship influence	Pregnant women only; self-reports
Garrison et al. (1983)	Framingham study participants; assessed 1949–1952	Nonsmokers 55% of highest weight group; smokers 80% of lowest weight group		Sample size, weights not given; no statistical evaluation
Goldbourt and Medalie (1977)	10,059 male government workers, aged 40–65	Current smokers 1/4 inch taller, 2.36 lb less than nonsmokers; ex-smokers in between; leaner skinfolds for smokers than ex-smokers and nonsmokers		Limited age range, employment group; smoking self-report
Gyntelberg and Meyer (1974)	5,249 employed men, aged 40–59, Denmark	Nondrinking smokers 1.5 percentile points lighter than nondrinking nonsmokers; light drinking smokers 2.9 percentile points lighter; heavy drinking smokers 5.9 percentile points lighter than drinking nonsmokers		All-male sample, one city; smoking self-report
Hjermann et al. (1976)	Approximately 16,000 male participants, aged 40–49, coronary risk factor screening, Oslo	Aged 45–49 smokers body weight 3.09 lb less than nonsmokers; aged 40–44 difference not significant; no group weight/height^2 index differences	Smoking rate: heavy smoker (>20/day) body weights higher than lighter smoker Age: older smokers (45–49) weighed less than nonsmokers; younger smokers (40–44) no effect	Smoking self-report; limited age range; one city; all men

TABLE 2.—Continued

Study	Design and sample	Major results	Moderator variables	Limitations
Holcomb and Meigs (1972)	226 manufacturing company male hourly employees, aged 55–59	Mild to moderate smokers 14 lb lighter than never smokers, ex-smokers, and heavy smokers	Smoking rate: heavy smokers (>1 pack/day) heavier than lighter smokers, equivalent to nonsmokers	Smoking self-report; limited age, incomes; all men
Huston and Stenson (1974)	184 men, British Field Regiment	≤10 mm subscapular skinfold men averaged 22 cigarettes/day; ≥15 mm subscapular skinfold men averaged 12 cigarettes/day		Limited male sample; smoking self-report; no separate smoker/nonsmoker data
Jacobs and Gottenborg (1981)	3,291 white men and women, aged 20–59, no cardiovascular disease or elevated risk factors; randomly selected middle-class suburb census tract blacks	Smokers lighter than never smokers and quitters	Smoking rate: male moderate smokers (14–29 cigarettes/day) 6.39 lb lighter than nonsmokers, 2.65–9.93 lb lighter than light and heavy smokers; female moderate smokers 5.07 lb lighter than never smokers, 1.54–8.38 lb lighter than heavy smokers Age: moderate/never smoker weight difference increased with age	Smoking self-report; restricted population
Khosla and Lowe (1971)	10,482 male steel workers, Wales	Per weight/height^2 index, smokers lighter than nonsmokers	Smoking rate: heavy smokers (>35 cigarettes/day) heavier than moderate smokers (15–34) Age: group weight differences increased after age 35	Smoking self-report; restricted population
Kittel et al. (1978)	8,284 male factory workers, Belgium	Relative weights significantly lower for cigarette smokers than never smokers, ex-smokers, and pipe/cigar smokers		Limited population, risk factor Rx program

TABLE 2.—Continued

Study	Design and sample	Major results	Moderator variables	Limitations
Kopczynski (1972)	3,039 random selectees, pulmonary disease study, Poland	Nonsmokers heavier than smokers, except 20-year-old men	Sex, age, smoking rate; no smoking-weight relationship influence	Smoking self-report; weights not reported
Lincoln (1970)	3,220 male household heads, aged 41–70, across United States	Smokers weighed 3–14 lb less than nonsmokers	SES, smoker/nonsmoker weight difference increased as income decreased Smoking rate: heavy smokers (≥21 cigarettes/day) weighed 4 lb more, moderate smokers (11–20 cigarettes/day) 4 lb less than all-smoker average	Restricted population; men
Matsuya (1982)	90 telephone employees, Japan	Ex-smokers weighed 5.29 lb more than nonsmokers; light smokers 2.87 lb less, heavy smokers 0.44 lb less than ex-smokers		Small, nonrepresentative sample; data self-report
Nemery et al. (1983)	210 steelworkers, aged 45–55, ≥10 years' service, Belgium	Smokers weighed 12.13 lb less than never smokers, 14.33 lb less than ex-smokers		Restricted population; smoking self-report
Stamford et al. (1984a)	164 (56 smokers, 108 nonsmokers) premenopausal women; smokers ≥20 cigarettes/day, ≥5 years, inhale	Smokers weighed 11.96 lb less, had lower average Quetelet Index than nonsmokers		Small sample size; premenopausal women only; data self-report
Stamford et al. (1984b)	269 adult men, fitness center screened, smokers: ≥20 cigarettes/day, ≥5 years, inhale	Smokers weighed 14.99 lb less, had 12% less body fat than nonsmokers		Select sample, exercising men; smoking self-report; heavy smokers

TABLE 2.—Continued

Study	Design and sample	Major results	Moderator variables	Limitations
Stephens and Pederson (1983)	15,518 persons aged >10; questionnaire, anthropometry	Smokers weighed less than nonsmokers; female smokers weighed 1.32 lb more to 5.73 lb less than female nonsmokers; men weighed 3.09–7.7 lb less; smokers averaged 3.445 lb less than nonsmokers		White women self-report, smoking self-report; no statistical significance tests
Sutherland et al. (1980)	Random sample, 175 men and women, rural town, New Zealand	Weight/height^3 index and skinfolds significantly higher in nonsmoking than smoking women; higher for nonsmoking men, but not significant	Sex: male smokers not significantly leaner than nonsmokers; smoking women lighter than nonsmoking women	Smoking self-report; small sample size
Waller and Brooks (1972)	2,169 health exhibit visitors	"Little weight difference" among current smokers, nonsmokers, and ex-smokers		Smoking self-report; bathroom scale weight; health-conscious population; high % cigar/pipe smokers; no statistical evaluations
Zeiner-Henriksen (1976)	Approximately 15,000 randomly selected Norwegians	Current smokers average and relative weight lower than nonsmokers or ex-smokers		Smoking and weight self-report, questionnaire

TABLE 3.—Longitudinal evaluations of smoking and body weight

Study	Design and sample	Major results	Moderator variables	Limitations
Blitzer et al. (1977)	57,032 women, aged 20–59, self-help weight loss groups	Quitters gained 7.0–10.2 lb more than continuing smokers	Smoking rate: weight gain/previous smoking rate proportional	Smoking and weight self-reports; all women trying to lose weight
Bosse et al. (1980)	1,749 adult men, Normative Aging Study, assessed over 5 years	Average 5-year gains: never smokers 1.81 lb; former smokers 1.87 lb; current smokers 2.00 lb; ex-smokers who quit 6.34 lb	Age: younger quitters gained more Adiposity: fatter quitters gained more Tar rate: higher present tar rate smokers gained most Anxiety: high related to higher gain	Smoking self-reports; all men; actual weights not presented
Burse et al. (1982)	4 paid volunteers; 11-day baseline, 21-day quit period, 20-day resumption period	3 of 4 gained weight; 1.98 lb increase during cessation; 1.76 lb loss on resumption		Very small sample, paid volunteers; short-term evaluation
Cambien et al. (1981)	1,067 Paris civil servants, aged 25–35, screened, randomly assigned, cardiovascular risk factor reduction intervention or control groups; 2-year followup evaluation	Treatment group quitters gained 4.85 lb, control group quitters 7.50 lb; nonsmokers and no-change smokers gained 1.54 lb in treatment group, 2.2 lb in control		Smoking self-report; risk factor reduction program participants
Carney and Goldberg (1984)	13 women, 5 men, aged 23–67, smoked ≥20 cigarettes/day, ≥5 years; 12 male controls; 15 smokers abstained 2 weeks	Quitters weight change range: −3.09 to −9.0 lb	Smoking rate/duration: no weight change relationship Biological variables: weight gain positively related to lipoprotein lipase activity in adipose tissue	Smoking self-report; controls weight; changes not reported; short-term evaluation

TABLE 3.—Continued

Study	Design and sample	Major results	Moderator variables	Limitations
Coates and Li (983)	373 male asbestos-exposed smokers, aged ≥42; 87% white, mean education 12.8 years; 12 months assessment after cessation effort	Continuous quitters gained 5.15 lb; continuous smokers gained 0.35 lb		Smoking self-report; all male, nonrandom sample
Comstock and Stone (1973)	502 male telephone workers, aged 40–59, mostly white; 2 assessments 5 years apart	5-year followup average gains: never smokers 2.43 lb, ex-smokers 5.07 lb, continuing smokers 2.42 lb; quitters 11.24 lb and showed greatest skinfold increases	Smoking rate: increasing quitter weight gain with heavier prequit smoking	Smoking self-report; men only
Dallosso and James (1984)	16 (8 men, 8 women) antismoking clinic participants; mean age, men 47.1, women 35.4, assessed before and 6 weeks after clinic	10 quitters gained 3.00 lb; 5 continuing smokers lost 0.99 lb		Small sample size; smoking self-report; limited followup
Emont and Cummings (1987)	125 stop-smoking clinic participants; pretreatment and 1-month followup assessments	76% quitters and slippers (≤5 cigarettes/day) averaged 5.8 lb gain	Nicotine gum: gain/gum use reliable negative correlation for heavy smokers; gain not related to age, sex, marital status, baseline body weight	Weight gain, smoking self-report, confounded by gum use; limited followup; incomplete data
Fagerstrom (1987)	26 nicotine gum users; abstinent at 6 months	Infrequent gum users gained 6.83 lb, frequent users 1.98 lb	Nicotine gum, frequent users gained less weight	Small sample size; measures unclear
Friedman and Siegelaub (1980)	Multiphasic health checkup patients; smoked, then quit 12–18 months later (N = 3,825) or continued (N = 9,392)	Quitters gained 2–3 lb more than continuing smokers	Smoking rate: higher initial smoking rate related to greater weight gain after cessation	Smoking self-report; whites only data

TABLE 3.—Continued

Study	Design and sample	Major results	Moderator variables	Limitations
Garn et al. (1978b)	6,979 women followed through ≥2 pregnancies	Higher prepregnancy weights for habitual nonsmokers than habitual smokers: whites 3.4 lb, blacks 4.1 lb; lower habitual smoker gains between pregnancies for both races	Race: no weight/smoking relationship influence	Smoking self-reports; restricted population
Garvey et al. (1974)	870 white male veterans, aging study, assessed 4–7 years after initial assessment	Smoking/weight change significantly related; recent quitters (≤5 years) gained 4.19 lb more than smokers, nonsmokers, former smokers	Age: 40–54 quitter weight increase greatest	Smoking self-report; exact quit date unknown
Glauser et al. (1970)	7 male smokers, cessation program; assessed preprogram, 1 month postprogram	At 1-month followup, participants gained 6.4 lb		Smoking self-report; exact quit date unknown
Gordon et al. (1975)	4,796 Framingham study participants: 1,496 male smokers, 492 male nonsmokers, 1,634 female nonsmokers, 1,174 female smokers; examined short-term changes after biennial exam 1, long-term effects between biennial exams 4, 10	At entry, male smokers weighed 8.0 lb less than nonsmokers; short-term male quitters gained 3.8 lb, nonsmokers 0.5 lb, continuing smokers 0.3 lb, new smokers lost 9 lb; too few female quitters to evaluate		Smoking self-report; change analysis, men only
Gormican et al. (1960)	301 pregnancy obstetrics records, women, aged 17–35	Smoker, nonsmoker prepregnancy weight similar; no last 2 trimester weight gain difference (nonsmokers 24.6 lb, smokers 22.6 lb)		Clinic record data; pregnancy weight gain data only

TABLE 3.—Continued

Study	Design and sample	Major results	Moderator variables	Limitations
Grimstead (1981)	45 subjects (38 women, 7 men), average age 40; evaluated 6 months after cessation treatment; saliva thiocyanate verification	During program, 63% subjects averaged 2.88 lb increase, 34% averaged 2.46 lb decrease; at followup, 37% averaged 6.97 lb gain, 43% averaged 3.27 lb loss		Questionnaire, phone interview data
Gritz et al. (in press)	554 self-quitters (245 men, 309 women), mean age 41.4, 85% Caucasian, 9% black, 4% Asian, 1% Asian-American, 1% Native American; 1-year followup	35% previous quitters gained, 3% lost; at 1 year, abstainers averaged 6.1 lb gain; relapsers gained 2.71 lb while abstinent, lost 1.3 lb upon relapse; continuous smokers gained 0.3 lb		Questionnaire, phone interview data
Grossarth-Maticek et al. (1983)	1,353 subjects, Yugoslavian village of 14,000; every 2d household oldest member; evaluated 1965–1966, 1969	Smoking reduction/weight increase relationship (regression coefficient −0.30)		Smoking self-report; weights, weight changes not reported
Gunn and Shapiro (1985)	89 cessation clinic participants; all quit at initial evaluation; 3-month followup assessment	43 of 54 (80%) quitters gained 2–30 lb		Smoking, height, weight self-report; inadequate statistical evaluation
Hall et al. (1986)	253 smoker participants (122 men, 133 women) 2 smoking treatment trials; 6-, 12-month followups; biochemical verification	Abstainers gained more than smokers at 1 year	Smoking rate: pretest smoking level/postcessation weight gain positively related; Chronic dieting: chronic diet subjects gained most	Multiple Rx (e.g., nicotine gum participant data included
Hatsukami et al. (1984)	27 smokers hospitalized 7 days; 20 subjects smoked 3 days, then quit 4 days; 7 control group subjects smoked throughout	Quitters gained 1.76 lb in 4 days		Small sample size; inpatient environment

TABLE 3.—Continued

Study	Design and sample	Major results	Moderator variables	Limitations
Haworth et al. (1984)	6361 women (234 nonsmokers, 302 smokers) interviewed last prenatal visit (18%) or within day after delivery (82%)	No smoker/nonsmoker pregnancy weight gain difference		Smoking self-report; pregnancy weight gain data only
Hickey and Mulcahy (1973)	160 men (124 smokers); 6-month, 2-year followups after myocardial infarction	Quitter, reducer, continuing smoker differences not significant		Smoking self-report; postmyocardial infarction may motivate healthy behavior
Holme et al. (1985)	16,202 Oslo men, aged 40–49, screening program; 1,232 (elevated cholesterol or upper quartile coronary risk score) randomly assigned diet/smoking intervention or control; 5-year followup	17% controls, 24% intervention quit; 1- to 2-year-quitter weight increased more than controls, then decreased to below prequit level		Smoking self-report; confounded by high cardiovascular disease risk health intervention; weights not reported
Howell (1971)	Retrospective, 1,121 men, aged 40–54; 15- to 20-year weight gain examinations	Light smokers (<20 cigarettes/day) gained 1.9 lb less than heavy smokers, 3.1 lb less than ex-smokers, 3.6 lb less than never smokers	Smoking rate: lower rate related to less weight gain	Retrospective report
Hughes and Hutchinson (1983)	37 smokers and 19 ex-smokers with pulmonary emphysema followed ≥3 years	Smokers lost 0.32 lb/yr, ex-smokers gained 1.17 lb/yr; significant difference		Smoking self-report; pulmonary emphysema population

TABLE 3.—Continued

Study	Design and sample	Major results	Moderator variables	Limitations
Jenkins et al. (1973)	2,318 men (546 never smokers, 359 previous quitters, 547 light smokers, 866 heavy smokers), aged 39–49, 11 California corporations in Western Collaborative Group Study; changes assessed since age 25; 1960–1969 study	Weight loss more likely for light and heavy smokers than never smokers and quitters		Smoking self-report; weights not presented
Kramer (1982)	175 subjects, commercial cessation program (41 nonparticipants or nonlocated, 59 quitters, 75 continuing smokers) ≥1-year followup	76% nonsmokers, 56% smokers gained weight; these smokers mean gain 1.7 lb, these nonsmokers mean gain 3.0 lb		All data self-report; high attrition, data loss; presentation incomplete
Lund-Larsen and Trefil (1982)	12,329 men and women, aged 20–49, cardiovascular disease project; 2 screenings 3 years apart	Smokers mean and relative weight less than nonsmokers; female quitters gained 5.95 lb, male quitters 7.84 lb; smoking-starter men lost 1.98 lb, women 5.5 lb; smokers and nonsmokers little/no change	Sex: men, women weight change/smoking cessation and initiation similar	Self-report
Manley and Boland (1983)	39 male, 55 female smokers, cessation program; randomly assigned, 1 of 3 4-week treatments or attention placebo control; 3-month followup; CO verification	31% abstinent at followup; abstainers averaged 10.93 lb gain, relapsers 6.92 lb		Relapser definition unclear

TABLE 3.—Continued

Study	Design and sample	Major results	Moderator variables	Limitations
Noppa and Bengtsson (1980)	1,302 Swedish women, aged 38–60	Current smokers leaner than nonsmokers; At 6 years, quitters gained 7.72 lb; smoking-starters lost 1.54 lb, nonchangers gained 3.09 lb		Smoking self-report
Pincherle (1971)	222 upper-class male quitters; followup ≥ 1 year after first visit	28% gained weight; 22% lost		Smoking self-report; limited population; incomplete report; no weights presented
Powell and McCann (1981)	29 women, 22 men, 5-day cessation project; 2- and 6-month followup	At 2 months, 54% gained weight, range 3–20 lb, mean 8.96 lb; all subjects mean 4.69 lb		Smoking self-report; no separate abstainer, smoker data; small sample size
Puddey et al. (1985)	66 cessation program volunteers, pair-matched by age, sex, body mass index; randomly assigned experimental, control groups; 2-week baseline, 6-week treatment, 6-week followup; thiocyanate, CO verification	14 quitters gained 3.97 lb; controls 0.44 lb		Small sample size
Rabkin (1984)	40 male, 67 female smokers, assigned to 3 cessation groups; followup 3 weeks post-completion; biochemical verification	67.3% gained weight, average 1.76 lb, skinfold increase 6.6 mm	No age, age at smoking start, rate, relative weight, anxiety correlation to male or female weight change	Small sample size, weight self-report

TABLE 3.—Continued

Study	Design and sample	Major results	Moderator variables	Limitations
Rantakallio and Hartikainen-Sorrin (1981)	12,068 pregnant women, n. Finland, 1966; 15% smokers (smoked after 2 months pregnant); nonsmoking controls matched for age, parity, place of residence, marital status	No smoking/nonsmoking pregnancy weight gain difference		Pregnant women only; smoking self-report; pregnancy weight gain data only
Rush (1974)	162 low-income urban pregnant women, no known medical problems, <140 lb preconception weight; had borne low birthweight infant; randomized controlled nutritional supplementation trial	Mean pregnancy weight gain lower for smokers (0.73 lb/wk) than nonsmokers (0.90 lb/wk)	Smoking rate; higher rate related to lower pregnancy weight gain	Pregnant women only; smoking self-report; pregnancy weight gain data only
Schoenenberger (1982)	4,421 male MRFIT volunteers, aged 35–57, good health but upper 10–15% coronary risk factor score; randomly assigned to intervention or control groups; followup 3 annual visits	With MRFIT intervention, significant body weight decrease in smokers (mean 4.6 lb), nonsmokers (mean 5.8 lb), reducers (mean 3.75 lb); quitters average weight change minimal (mean 0.55 lb)		Smoking self-report; confounded by risk factor reduction program participation; restricted population
Seltzer (1974)	794 adult white male veterans, average age 45; Normative Aging Study; screened for "high" health level, geographic stability; 214 screened at 5 years	At admission, ex-smokers 5.9 lb heavier than nonsmokers, 8.1 lb heavier than current smokers; at 5 years, quitters gained 8.0 lb, continuing smokers 3.5 lb		White veterans; smoking self-report

TABLE 3.—Continued

Study	Design and sample	Major results	Moderator variables	Limitations
Stamford et al. (1986)	13 sedentary women, 48-day successful quitters; 1-year followup	At 48 days, weight increased 4.85 lb; at 1 year, quitters increased 18.07 lb; 3 relapsers reduced weight to baseline levels; per hydrostatic weighing, gain was 96% fat		Small female sample; smoking self-report
Tuomilehto et al. (1985)	10,940 cardiovascular disease prevention program participants, aged 25–59, random sample, e. Finland; selectees with high blood pressure or hypertensive medicine assessed 5 years apart; smoking data from 2,264	Quitters body mass increased 2.31 lb/m²; starting smokers decreased 1.46 lb/m²		Smoking self-report; hypertensives
Vandenbroucke et al. (1984)	3,091 Netherlands civil servants, spouses (1,583 men, 1,508 women), aged 40–65, general health exam; 25-year followup	76.6% lean, 65.1% obese men smoked; 22.1% lean, 11.3% obese women smoked		Smoking self-report; restricted population

Gottenborg 1981; Khosla and Lowe 1971) documented increasing weight differences between smokers and nonsmokers with advancing age. Typically, aging smokers failed to gain as much weight as aging nonsmokers.

Three evaluations systematically compared males with females (Bjelke 1971; Kopczynski 1972; Sutherland et al. 1980). Two of the three (Bjelke 1971; Sutherland et al. 1980) reported the differences in body weight between smokers and nonsmokers to be greater in females than in males.

Longitudinal Evaluations of Smoking and Body Weight

Table 3 presents the results of 43 longitudinal evaluations of the effects of smoking on body weight. Consistent with the cross-sectional evaluations, the overwhelming majority (86 percent, 37 of 43) present evidence that smokers who quit smoking gain weight, that people who quit smoking gain more weight than nonsmokers, and that people who initiate smoking lose weight relative to nonsmokers. Of the six studies that did not find these relationships, three limited their examination to smoking and weight changes in pregnant women (Gormican, Valentine, Satter 1980; Haworth et al. 1980; Rantakallio and Hartikainen-Sorri 1981), two relied on participants making broad cardiovascular risk factor reduction efforts in subjects at high risk for cardiovascular disease (Hickey and Mulcahy 1973; Holme et al. 1985), and the remaining study supplied incomplete reports of the data (Kramer 1982). Of those studies on the effects of smoking cessation on weight, the length of followup ranged from 4 days to 7 years. According to these investigations, those who quit smoking gained an average of 6.16 lb (range: 1.76 to 18.07) during the year after cessation.

Daily cigarette consumption was the only moderator variable that received sufficient attention in this group of studies reaching specific conclusions. Seven of nine studies (78 percent) (Blitzer, Rimm, Giefer 1977; Bosse, Garvey, Costa 1980; Comstock and Stone 1972; Friedman and Siegelaub 1980; Hall, Ginsberg, Jones 1986; Howell 1971; Rush 1974) reported a positive relationship between cigarette consumption and weight change; that is, as pretest cigarette consumption increased, postcessation weight gains also increased. Two studies (Carney and Goldberg 1984; Rabkin 1984) did not find a relationship between cigarette consumption and postcessation weight gain.

In summary, there is substantial evidence of an inverse relationship between cigarette smoking and body weight. Of 71 studies reported since 1970, 62 (87 percent) collectively indicate that smokers weigh less than nonsmokers and that people who quit smoking gain weight. Older smokers, females, and those smoking approximately one pack of cigarettes/day may experience the

largest weight control effects of cigarette smoking. Smokers who smoke heavily tend to gain the most weight following smoking cessation. These generalizations are consistent with reviews based on other studies reported since 1880 (Grunberg 1986a). Not all smokers who quit smoking gain weight. Further, for ex-smokers who do gain weight, the amount of weight infrequently poses a serious health risk.

The Role of Nicotine

Animal studies indicate that nicotine administration results in weight loss or decreased weight gains and that cessation of nicotine results in body weight gains greater than those of controls (Bowen, Eury, Grunberg 1986; Grunberg 1982, 1985, 1986b; Grunberg, Bowen, Morse 1984; Grunberg, Bowen, Winders 1986; Grunberg, Winders, Popp 1987; McNair and Bryson 1983; Morgan and Ellison 1987; Schechter and Cook 1976; Wager-Srdar et al. 1984; Wellman et al. 1986). Most of these studies report inverse dose–response relationships between nicotine and body weight.

Recent research on nicotine polacrilex gum with humans corroborates the role of nicotine in body weight effects. Fagerström (1987) reported that subjects who quit smoking were much less likely to gain weight when they consistently used nicotine polacrilex gum. Abstinent subjects who regularly used the gum gained less than 2 lb at a 6-month followup. In contrast, the infrequent gum users gained almost 7 lb ($p<0.05$). Emont and Cummings (1987) reported a significant negative relationship ($r=-0.37$) between the number of pieces of nicotine polacrilex gum chewed per day and weight gain for heavy smokers (>26 cigarettes/day). No such relationship between gum use and weight gain was observed for lighter smokers (<26 cigarettes/day).

Mechanisms Underlying The Relationship Between Smoking and Body Weight

The inverse relationship between smoking and body weight may result from changes in energy intake, changes in energy expenditure, or both. Energy intake involves dietary intake. Energy expenditure is affected by behavioral factors (physical activity) and biological factors (e.g., metabolism). These potential mechanisms are examined below.

Dietary Intake

Several prospective investigations have evaluated dietary intake changes following smoking cessation in humans. Hatsukami and coworkers (1984) hospitalized 27 smokers for a 7-day period. After a 3-day baseline, 20 of the subjects were deprived of smoking for 4 days while the remaining 7 served as a control group. During this 4-day period of abstinence, caloric intake increased significantly (from 1,397 to 1,651 kcal), which corresponded with a significant 1.76-lb increase in weight. In the most comprehensive study to date, Stamford and coworkers (1986) evaluated changes in dietary intake, physical activity, and resting metabolic rate in 13 sedentary females who quit smoking for a 48-day period. Following smoking cessation, mean daily caloric consumption increased by 227 kcal, which accounted for 69 percent of the variance in postcessation weight gain (4.85 lb). Robinson and York (1986) followed 11 smokers who quit for 7 days. Mean dietary intake significantly increased, but changes in resting metabolic rate were not observed. Dallosso and James (1984) followed 10 subjects for 6 weeks after they participated in a stop-smoking clinic. There was a 4-percent drop in resting metabolic rate in smokers who quit, a drop which was reliable when the data were expressed per kilogram of body weight. The average dietary intake increased by 6.5 percent, but this difference did not reach statistical significance.

Preliminary results of a recent investigation indicate gender differences in the effects of short-term smoking cessation on body weight and food intake (Klesges, Meyers et al. 1987). Female smokers who quit for 1 week increased their body weight and dietary intake significantly more than male smokers who quit. This sex difference is consistent with animal studies (Grunberg, Bowen, Winders 1986; Grunberg, Winders, Popp 1987). Given females' marked concerns regarding postcessation weight gain (Klesges and Klesges, in press), future studies will need to investigate possible gender differences in response to smoking cessation.

Several studies indicate that smokers may differ from nonsmokers in their intake of sweet-tasting simple carbohydrates (sugar) in particular. In a human laboratory study, Grunberg (1982) observed that smokers who were allowed to smoke ate less sweet food than smokers who were not allowed to smoke or nonsmokers. Smokers not allowed to smoke also reported the greatest preference for sweet foods. There were no differences among the three subject groups in consumption of other types of foods. Rodin (1987) conducted a prospective study in which food intake after smoking cessation was carefully evaluated. Smokers who gained weight after quitting smoking increased their sugar consumption in particular. Further, smokers increase consumption of sweet snack foods when they are deprived of cigarette smoking (Duffy and Hull, in press; Perlick 1977). On the other hand, two early investigations (Bennett, Doll, Howell 1970; Richardson 1972) found *higher* sugar consumption in smokers relative to nonsmokers. However, Richardson (1972) found that this difference was because of low-sugar intake in ex-smokers, while Bennett, Doll, and Howell (1970) argued that the differences

were largely due to increased added sugar intake because of hot beverage consumption. These two studies, which are inconsistent with the more recent studies, did not carefully measure all food intake and did not assess intentional changes in food intake to control body weight.

Several animal experiments have documented that food intake decreases during nicotine administration and increases after administration has ceased and that these changes in food intake correspond with changes in body weight (Bowen, Eury, Grunberg 1986; Grunberg 1982; Grunberg, Bowen, Winders 1986; Levin et al. 1987; McNair and Bryson 1983; Wager-Srdar et al. 1984). Consumption of sweet foods by male rats is particulary affected by nicotine (Grunberg 1982; Grunberg et al. 1985). However, nicotine also reduces bland food intake in female rats and has a greater effect on body weight of female rats than of male rats (Grunberg, Winders, Popp 1987; Grunberg, Bowen, Winders 1986; Levin et al. 1987).

Several investigations have reported that changes in body weight in animals also occur without observing decreases in food intake as the result of nicotine administration (Grunberg, Bowen, Morse 1984; Schechter and Cook 1976; Wellman et al. 1986). In one investigation, chronic exposure to cigarette smoke reduced body weight and food intake in rats; however, hamsters exposed to cigarette smoke decreased body weight without reducing food intake (Wager-Srdar et al. 1984). Several methodological factors complicate these results, including the use of different strains of animals, different routes of administration and dosages of nicotine, and whether acute versus chronic effects of nicotine were reported. However, these results indicate that more than the mechanism of food intake was involved in producing nicotine- and smoking-related weight changes.

Data from short-term human studies and several animal experiments indicate that dietary intake is involved with smoking-related energy imbalance. Based on self-reported cross-sectional surveys, it has been reported that smokers' dietary intake is the same as (Albanes et al. 1987; Fehily, Phillips, Yarnell 1984; Fisher and Gordon 1985; Matsuya 1982) or significantly higher than (Picone et al. 1982; Stamford et al. 1984a,b) that of nonsmokers while the smokers simultaneously maintained a lower body weight. Assuming that smokers are not consistently biased in their reports of dietary intake, it appears that either differences in physical activity or metabolic rate are maintaining the body weight differences between smokers and nonsmokers.

Physical Activity

The data available from cross-sectional investigations, short-term prospective studies, and animal investigations seem to indicate that changes in physical activity do not play a role in either differences in body weight between smokers and nonsmokers or the weight gain associated with smoking cessation. Some cross-sectional investigations have found that smokers have *lower* levels of physical activity compared with nonsmokers (Kannas 1981). Others have not found differences in physical activity and physical fitness between smokers and nonsmokers (Gyntelberg and Meyer 1974; Stamford et al. 1984b; Stephens and Pederson 1983). A recent review (Blair, Jacobs, Powell 1985) that addressed the relationships among exercise, physical activity, and smoking concluded that smoking and physical activity are negatively associated; however, the relationship was extremely weak and variable.

Animal studies on the relationship between nicotine and physical activity have generally found that physical activity plays a small role or fails to correspond to decreases in weight during nicotine administration (Bowen, Eury, Grunberg 1986; Cronan, Conrad, Bryson 1985; Grunberg and Bowen 1985b). One study found that decreases in physical activity after cessation of nicotine appeared to contribute to postdrug body weight increases (Grunberg and Bowen 1985b), but this effect was quite small and occurred only in males.

A few prospective human investigations have evaluated physical activity changes following smoking cessation (Hatsukami et al. 1984; Hofstetter et al. 1986; Klesges, Brown et al. 1987; Rodin 1987; Stamford et al. 1986). These investigations found no changes in physical activity as a result of smoking cessation.

Metabolic Rate

Metabolic rate is an important consideration in energy imbalances associated with smoking cessation because approximately 75 percent of total energy expenditure is in the form of metabolism (Bernstein et al. 1983; Ravussin et al. 1982). Metabolism increases as the result of acute nicotine administration and immediate effects of smoking (Ghanem 1973; Ilebekk, Miller, Mjos 1975; Robinson and York 1986; Schievelbein et al. 1978; Wennmalm 1982). The major question, however, is whether these effects persist long enough to have a direct impact on body weight. Given that (1) smokers do not have higher levels of physical activity compared with nonsmokers (Blair, Jacobs, Powell 1985), (2) some studies report smokers' dietary intakes are the same as or higher than those of nonsmokers (Picone et al. 1982; Stamford et al. 1984a,b), and (3) smokers maintain lower body weights than nonsmokers, it is reasonable to postulate that changes in metabolism contribute to the relationship between smoking and body weight. Additionally, there are several reports in the literature on animals that have documented nicotine-induced reductions in body weight without a concomitant reduction in food intake (Grunberg, Bowen, Morse 1984; Schechter and Cook 1976; Wellman et al. 1986).

Direct evidence supporting a chronic metabolic mechanism that modulates the smoking/body weight relationship is beginning to emerge. Metabolic rate was chronically measured in a study of rat and hamster exposure to cigarette smoke (Wager-Srdar et al. 1984). Higher resting metabolic rates were observed on only one of the test days compared with the pretest in the rat investigation, while no significant differences were observed in the hamster study. Another recent investigation (Wellman et al. 1986) evaluated brown adipose tissue (BAT) thermogenesis at different levels of nicotine and caffeine injections. No differences in BAT thermogenesis were observed in response to either nicotine or caffeine. The group that received a combination of caffeine and nicotine showed a 63 percent increase in BAT thermogenesis.

The few studies that have evaluated metabolic rate changes in response to smoking cessation in humans have produced inconclusive results. Three investigations found metabolic changes after cessation in human smokers. An early report (Glauser et al. 1970) found decreases in oxygen consumption for seven male subjects who quit smoking for 1 month (neither food intake nor physical activity was monitored). A more recent investigation found a 4-percent drop in metabolic rate (reliable when data were expressed per kilogram of body weight) and no significant increase in dietary intake for 10 subjects who quit smoking for 6 weeks (Dallosso and James 1984). In the only study that used a respiration chamber, Hofstetter and others (1986) reported that total energy expenditure was 10 percent higher during a 24-hr period of smoking versus a 24-hr period of abstinence in eight smokers. No changes were observed in physical activity or mean basal (sleeping) metabolic rate (dietary intake was held constant). However, this difference in energy expenditure disappeared after 24 hr.

Three investigations did not find a change in metabolic rate as the result of smoking cessation. Burse and associates (1982, 1975) did not observe changes in resting metabolism in a sample of four smokers who quit for 3 weeks. This investigation did find reliable increases in desire for food, however. In another study, 11 smokers were studied after a 7-day period of smoking abstinence (Robinson and York 1986). Total energy expenditure following a meal did not change during the cessation period. Stamford and colleagues (1986) failed to find changes in oxygen consumption in 13 subjects who quit smoking for 48 days. This investigation did find marked dietary intake changes that accounted for 69 percent of the variance of postcessation weight gain.

There are several possible explanations for the inconsistency observed in the literature on metabolic rate. Different investigators have used different criteria (e.g., resting oxygen consumption, BAT thermogenesis) for operationalizing metabolism. It is possible that

previous dieting history (Brownell et al. 1986) and the use of nicotine polacrilex gum (Fagerström 1987) may directly impact the metabolic response to smoking cessation. It is not clear what the metabolic response to nicotine with added agents is likely to be. For example, one study found that while neither nicotine nor caffeine alone produced a change in BAT thermogenesis, the two combined increased thermogenesis by 63 percent (Wellman et al. 1986). This finding is particularly interesting given that smokers may be more likely to drink caffeinated beverages than nonsmokers (Blair et al. 1980). Finally, the available literature on human studies used very small subject groups, making it impossible to detect subtle but potentially meaningful changes in resting metabolic rate. The small sample sizes do not allow for an evaluation of variables that may potentially moderate the metabolic response to smoking cessation.

Summary of Mechanisms Literature

Changes in dietary intake appear to be involved in weight gains after cessation of smoking or cessation of nicotine administration. Physical activity plays little or no role in the relationship between smoking and body weight. The data on metabolic contributions to postcessation weight gain are suggestive, but further research is needed. Unfortunately, much of the relevant human research literature is characterized by small sample sizes, short followup evaluations, and inadequate evaluations of energy balance following smoking cessation. To date, only one investigation has comprehensively evaluated (i.e., simultaneous assessment of dietary intake, physical activity, and metabolic rate) energy balance changes as the result of smoking cessation. This was a sample of 13 sedentary females followed for 48 days (Stamford et al. 1986). Comprehensive, prospective evaluations of energy balance changes in response to smoking cessation are needed. Additionally, no study has evaluated possible long-term changes in dietary intake, physical activity, and metabolic rate as a result of smoking cessation. The longest followup period reported in the literature to date is 2 months (Dallosso and James 1984). Finally, evaluation of potential moderator variables of dietary intake, physical activity, and metabolic rate as the result of cessation is needed. Gender (Grunberg, Winders, Popp 1987; Klesges, Meyers et al. 1987), previous dieting history (Brownell et al. 1986; Hall, Ginsberg, Jones 1986), pretest levels of lipoprotein lipase (Carney and Goldberg 1984), and the use of nicotine polacrilex gum (Fagerström 1987) appear to be important variables influencing weight gain and need further investigation.